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► **To cite this version:**

H. Kim, F. Hashio, T. Sakurai. METAL-SEMICONDUCTOR (Si, GaAs) INTERFACES. Journal de Physique Colloques, 1989, 50 (C8), pp.C8-449-C8-451. 10.1051/jphyscol:1989876 . jpa-00229974

**HAL Id: jpa-00229974**

**<https://hal.science/jpa-00229974>**

Submitted on 4 Feb 2008

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## METAL-SEMICONDUCTOR (Si, GaAs) INTERFACES

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**Abstract** The FN plots for Si tips are classified into lines and curves depending on the thickness of the surface oxide film, but the FN plots for a GaAs tip shows only straight lines. A double peak structure in the energy distribution curve has been observed on the field desorbed surface at medium field after deposition of 1-2 ML of Al onto a Si surface. However, with increasing the amount of deposition of Al to 3 ML on the Si surface, the double peaks disappear completely. This result suggests that the surface layers are perfectly metallized even at room temperature. An oxide film, thinner than that on a Si surface, formed on the GaAs surface and the surface composite atoms of GaAs can easily be desorbed by field desorption. An intrinsic potential drop disappears suddenly at a certain field, that is, the surface region of the field desorbed tip is composed of metallic species.

### 1 - INTRODUCTION

In recent years, with increasing circuit density in VLSI, a great deal of interest has been focussed on the formation of interfaces between metals and semiconductors and their microscopic structure, that is, an understanding of an origin of electronic properties at an atomic level.

Two and three dimensional atomic structures of the interface have been studied using surface sensitive analysis methods such as Auger, high resolution TEM, SEM and STM respectively. In this study the desorption of surface oxide layers, bulk atoms, adsorbed layers and the composite layers of Al and Si, were measured using a probe hole FEM, the most sensitive tool for the detection of adsorbed species, and a retarding potential analyser which is able to detect a minute change in surface conductivity.

### 2 - EXPERIMENTAL PROCEDURE AND RESULTS

The experimental procedure and apparatus have been described in a previous paper /1/ and will, therefore, be described for GaAs only briefly. A(110) oriented, n-GaAs bar(0.4 x 0.4 x 7mm) was mounted on a Mo loop by a similar method to that of the previous paper. The sample was dipped in a boiling solution of one part of H<sub>2</sub>O, one part of H<sub>2</sub>O<sub>2</sub> and five parts of H<sub>2</sub>SO<sub>4</sub> until a tip radius of 500-1000Å was reached.

#### 2.1 Cleaning process

**2.1.1 FN plots for Si and GaAs.** After the pressure of the system reached 10<sup>-10</sup> Torr, field desorption was begun with a low field, which was increased step by step until a steady FN plot was obtained or the tip was ruptured by the high field. The surface characteristics of each field desorption process were recorded using FN plots, retarding potential and energy distribution curves. The FN plots for the Si tip are classified into lines or curves depending on the thickness of the surface oxide film. The amount of potential drop at the surface is in proportion to some extent to the curvature of the FN plot. However, the FN plots for GaAs are only lines regardless of the etching condition.

## 2.2 Clean Surface

2.2.1 Si. The behaviour of the clean surface of Si has been described previously and will, therefore, be discussed only briefly. The thickness of surface oxide formed on the Si surface depends on the etching condition and also it is concerned with the curvature of FN plots for surfaces covered with thick oxide, which bend down at high field. The more oxide film covering the surface, the more bent the FN plot which is obtained. The thicker oxide layers could not be desorbed at usual desorption fields. The Si surface can easily be metallized even at room temperature by less than a ML of Al adsorbed on it.

2.2.2 GaAs. In the cleaning process, there are three cases, i.e. (1) the potential drop at the surface is large and depends on the FE current, (2) the potential drop is small and independent of FE current, (3) the potential drop is a little and constant all over the desorption field. In the case of large potential drops, the value of  $V(th)$  decreased, with fluctuations in its magnitude. At a certain field, the value of  $V(th)$  became constant and independent of FE current. The value of  $V(th)$  kept constant on further increase of the field until the tip was ruptured. The clean surface was obtained at this field by desorbing the surface oxide and a part of the surface composite atoms as shown in Fig.1. By adsorption of Al, the work function of the clean surface was changed but on the contrary, there was no influence on the  $V(th)$  at clean surface.

## 3 - DISCUSSION

3.1 Metallic clean surface of GaAs. The value of  $V(clean, 2000-4900 V)$  is dependent on surface oxidation and tip radius. The fact that the value of  $V(th)$ , 4.0-6.5V, at  $V(clean)$  is independent of FE current suggests that the surface has metallic properties. It is well known that the atomic positions of the topmost layers of most semiconductor surfaces are not the same as their bulk positions. In the case of GaAs(110) which has equal numbers of surface Ga and As atoms, the topmost As atoms are believed to be displaced outward approximately 0.3 Å, while the topmost Ga atoms are displaced inward approximately 0.5 Å relative to ideal surface /2/.

When a high field was applied to the tip, the surface gradually became Ga rich as the protruding topmost As atoms can easily be desorbed. In the retarding potential curve, the values of  $V(th)$  reached some constant level. This means that the Fermi level is fixed to some constant value. The movement of the surface Fermi level position by adsorption of a minute amount of foreign atoms has been observed by W.E.Spicer et al. /3/. The  $V(th)$  at clean surface gives the relative value of the final Fermi level pinning position.

3.2 An intrinsically clean Si surface. Si surfaces prepared by electrolytic etching are of two types, having high and low surface conductivity respectively. When the field was increased to clean the surface, an intrinsic structure was developed at the topmost layers by desorbing the doped atoms preferably from the surface. The  $V(th)$  increased to a saturated value for the high conductive surface which corresponds to the linear FN plot. But the  $V(th)$  decreased to some constant value as the FD proceeded in the case for the low conductive surface, which corresponds to the bent FN plot, by desorption of the surface oxide layers.

3.3 Adsorption of Al on Si and GaAs. In this study, after a ML of Al was deposited on a high conductive clean Si surface,  $V(th)$  was measured as a function of  $V(FD)$ . The value of  $V(th)$  remained nearly constant and also independent of FE current on the first and second Al deposited surface. However, energy distribution curves for each process differ in shape, number of peaks and position of peaks, as shown in Fig.2. It is concluded from the above that a high energy peak arises from the deposited Al. On the first deposition of a ML of Al on the surface, a sharp metallic peak was observed at low field. Double peaks originated from the metal and substrate at medium field and a rather wide composite peak grew up at high field with increasing amounts of deposition. On further desorbing the overlayers, the threshold values were

shifted to high energy and the satellite peak disappeared at high field. In the case of the second deposition of a ML of Al on the surface, the satellite peak was more pronounced than in the previous case owing to the denser population of Al. On the contrary, in the third deposition of Al, only a sharp single, metallic, peak appeared at any field. A similar tendency was also seen for GaAs surfaces.

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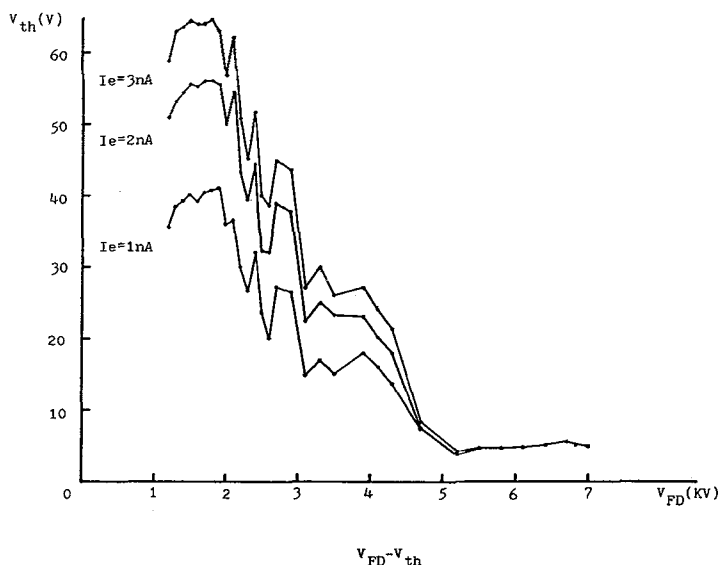
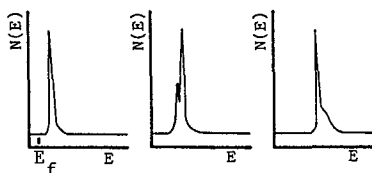
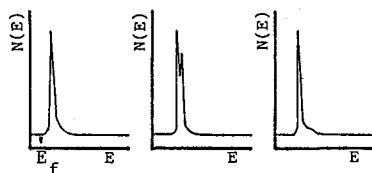


Fig.1 Variation of potential drop at GaAs(110) as a function of desorption field.

THE FIRST DEPOSITION OF AL



THE SECOND DEPOSITION OF AL



THE THIRD DEPOSITION OF AL

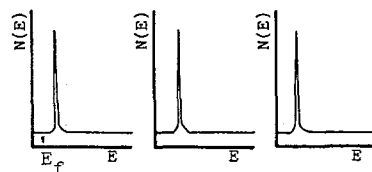


Fig.2. Energy distribution curves as a function of the amount of adsorbed Al and desorption field (increased left to right)

- top : Energy curves for FD surface after a ML of Al deposited on Si.
- middle : Energy curves for the second deposition of Al on the upper right surface.
- bottom : The same as the above two cases after deposition of Al on the right part of the middle specimen.